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DEPARTMENT OF COMMERCE -- BUREAU OF MINES

# ELECTRICAL ACCIDENT PREVENTION[1]

By L. C. Ilsley[2]

## PREVENTION OF ELECTRIC SHOCK

The first thing to consider in prevention of electric shock is the voltage of the circuit. No person can be sure that he will not be killed, even from a 110-volt circuit, if he makes proper contact with the circuit so as to cause the maximum current to pass through his body. As the voltage is increased to 250 volts, 500 volts, or 2,300 volts the danger from contact with the electric circuit is increased. Alternating current of the same nominal voltage is possibly more dangerous than direct current. Experience has taught us that both will cause death, and that if the fatalities from this source are to be kept low, certain precautions in the guarding of circuits must be observed.

### Safeguarding Surface Machinery and Apparatus

The frames of electric motors installed on the surface should be grounded to prevent shock in case they become charged with electricity because of the breaking down of the insulation. Where there is danger of accidental contact with live or moving parts, such parts should be isolated by suitable guards. This rule applies to transformers, high-voltage connections back of switchboards, etc. Trolley circuits, also feeder and lighting circuits, should have sufficient clearance from the ground to prevent accidental contact. If this is impossible, these circuits should be protected by adequate guards. Workmen or attendants who work on or around live electrical machinery should be protected by insulating mats, or by other equivalent means, to prevent serious results in case of accidental contact with live parts.

### Safeguarding Underground Machinery and Apparatus

Owing to lack of space, moisture, insufficient light, etc., it is more difficult to safeguard the underground worker than the surface employee. All underground stationary motors, switchboard frames, and metallic casings of electrical parts should be permanently and effectively grounded. Portable

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2 - Electrical engineer, U. S. Bureau of Mines Pittsburgh Experiment Station, Pittsburgh, Pa.



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motors whose frames are not in intimate contact with the earth should likewise have such frames grounded. Sub-stations and other places where it is dangerous for man to loiter should be fenced off, and only such men as are required in the routine work of the mine should be permitted to enter such enclosures. The maximum feasible clearance should be afforded all circuits, and, in so far as practicable, electric circuits should be run on one side of the entry only. Where men have to work or travel under trolley wires or other circuits, such circuits should be guarded. When men are working on an electric circuit, precaution should always be taken to insure that such circuits shall be dead and can not be unexpectedly made alive by the closing of the switch.

One of the recent steps towards safety is the wireless mine. Although the chief idea in keeping all wiring out of a mine is to prevent explosion hazards, there is also an advantage from the standpoint of electric shock. Several larger operators already have taken steps towards using storage-battery locomotives for all classes of work, thus doing away with any permanent wiring inside the mine. In such a mine there could be no deaths from overhead trolley or feeder circuits, a type of accident that accounts for a large proportion of the electric shock fatalities in the present-day mine.

## PREVENTION OF GAS IGNITION

There are three conditions which make possible a gas ignition from an electric source in a mine: (1) An accumulation of explosive gas; (2) a flash or arc from an electric circuit or machine; and (3) a flash or arc taking place at the point where the accumulation of gas has occurred, or at some point to which the gas accumulation has been moved by air currents or other means. The amount of gas accumulation which is necessary for ignition lies between the limits of 5 to 15 per cent methane. The quantity of spark or flash necessary is exceedingly small; for instance: a tiny spark from a small hand-operated blasting machine is sufficient; the heat stored by the glowing filament of a 2-volt, 1-ampere bulb is likewise sufficient; the tiny spark given off by the commutator of an electric coal drill under no load has been found to ignite gas readily; the spark from the usual mine incline signalling wires has ignite gas; and the spark from most of the mine telephones in use will also furnish sufficient heat to ignite gas.

Accident prevention, therefore, means the keeping of any tiny spark or flash away from the place where any possible accumulation of gas may occur. Electrical apparatus approved by the U. S. Bureau of Mines f[illegible]n atmospheres which may inadvertently contain gas in dangerous prop[illegible] is safeguarded in various ways. Electric lamps of permissible type [illegible]ovided with a bulb-ejecting device which throws the bulb out of contact [illegible] the bulb glass is broken, thus cooling down the glowing filament and [illegible]ng it from igniting any surrounding gas. The spark-producing parts of [illegible] motors are so enclosed that any sparks or flashes produced within the e[illegible] during operation will only ignite mixtures within the compartments; [illegible]partments themselves are so designed that flames are retained within t[illegible]rtments



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in which they originate and any gaseous mixtures in the surrounding atmosphere remain unexploded. Approved shot-firing devices are so designed that the spark produced in their operation will not ignite gaseous mixtures.

## Substandard Explosion-Proof Equipment

In many mines there is a great deal of apparatus which may, from the standpoint of safety, be considered substandard. Much of this equipment, although built along explosion-proof lines, would allow flames to pass through the joints, and from the Bureau of Mine's standpoint it falls considerably short of the standard now set for explosion-proof equipment.

The advantages of permissible equipment are as follows:

Permissible compartments are subjected to actual tests to prove their mechanical strength; tested in gas to prove their ability to retain all flames within the enclosure; inspected to insure that they have no through openings into their interior; and examined to see that all bolts are in place and securely fastened. Permissible compartments also receive special attention with respect to entrance of all wires. This point is frequently overlooked in unapproved equipment.

These permissible equipments are constructed in accordance with drawings held on file with the U. S. Bureau of Mines. To retain permissibility their design can not be modified without due consideration of the effect of such changes on safety. They receive special attention while being manufactured. Most companies have special factory inspection sheets to be filled out at the factory for each approved machine, listing numerous points that need specific attention. As the purchaser of permissible equipment has made a special effort to get the safest equipment procurable he will take greater interest in seeing that it is properly operated and maintained. Every permissible machine is provided with an approval plate which identifies it as a product approved by the Bureau of Mines.

## PREVENTION OF DUST IGNITION

At the present time more attention is being given to coal-dust propagation of explosions than to any other line of hazards. This is rightly so because of the extent of the havoc and disaster which may result from extension of an explosion by coal-dust. Sufficient attention has not been given to the rapidly extending hazard of initiation of explosions by coal-dust in conjunction with an electric arc, even where no explosive gas is present. The condition which is favorable to a coal-dust explosion of electric origin is a dense dust cloud in the presence of an electric flash. A dense dust cloud can occur in various ways; for example: a fall of coal or rock may stir up dry dust on the sides or bottom of the roadway or close to faces where electrically operated machinery is in use; a runaway trip may knock down timbers and release stored dust; a blow-out shot may raise dust in the room; a coal-cutting machine or a loading or conveying machine operating in dry coal beds may in their regular daily operation create clouds of dust; where dry coal is dumped on a belt, into a hopper, or into a car a dust cloud will probably result. In fact, there are few places in mines where electrical machinery is in operation that there is not danger of dust ignitions from electric arcs.



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An electric flash may occur from a broken lamp bulb, the operation of a fuse, the operation of a circuit-breaker, or a switch, from the flash of commutators, the arc of a trolley wheel, the arc of a broken trolley wire, light wire, or feeder circuit, from a short-circuit of a lighting or feeder circuits, and in many other ways too numerous to mention. Fortunately for the safety of mines, the coincidence of an electric flash in the midst of a properly constituted dust cloud occurs infrequently, or else mining would be much more hazardous than it is now. However, some very bad disasters have been attributed to this combination of circumstances; two of the most disastrous were attributed to runaway trips on slopes which stirred up dust clouds and at the same time damaged the electric wiring so that dust explosions occurred which resulted in death tolls of 90 and 120 men.

## Indirect Hazard to be Feared Most

The greatest danger from a dust explosion is not the direct ignition but the indirect ignition--that is, whereas it may be difficult to get just the right combination for an electric ignition of coal-dust, it is comparatively easy to ignite a small pocket of gas; under some circumstances as small a quantity as 100 cubic feet of an explosive mixture of gas and air may be sufficient to start a widespread explosion with coal-dust as the propagating or extending medium. The ignition of such a quantity of gas may in turn stir up enough dust to continue the explosion throughout the mine and be several hundred times as disastrous as the gas explosion alone would have been.

In looking for a preventive of dust explosions one must therefore eliminate not only direct ignition of dust by electric arcs, but also prevent gas ignition at the working face. If gas ignitions do occur, the dust throughout the mine should be so thoroughly saturated with moisture or rendered inert with noncombustible material as to be incapable of carrying on the explosion.

The Bureau of Mines is working in many ways to prevent coal-dust explosions. Recommendations are published from time to time covering regulations for electrical installations; flame safety lamps and electric lamps are tested for practicability and safety and are recommended for replacing open lights; electric shot-firing is advocated for all mines; motors for various services, storage-battery locomotives, and flame safety lamps are investigated to determine their safety for use in dusty atmosphere--that is, although these equipments are chiefly tested in gassy atmospheres, certain of the tests are made in dust-laden atmospheres to insure their safety in dusty mines; and finally, great emphasis is being given to the necessity and advantage of rock-dusting in order that the condition for ignition of coal-dust shall be absent.

## EXPLOSIVES HAZARD PREVENTION

In present-day mining, electricity, and the successf[illegible]ing of explosives are closely associated. The electric method, by [illegible] the electric detonator, is becoming popular for firing shots. Some [illegible]al means must be had for producing the current to heat up the bridge [illegible] the detonator. A number of electrical problems are involved in gettin[illegible] electric current to the detonator in the amount needed, when it is ne[illegible]ed, and in keeping it away from the detonator at all other times.



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An electric detonator may require only 0.35 to 0.50 ampere to fire it, so that there must be no stray amperes loitering in rails, pipes, coal ribs, etc., where they may come in contact with the ends of detonator wires; neither can one be careless with these ends when near an electric circuit, no matter how low the voltage or seemingly insignificant the circuit may be; it is advisable that the ends of all detonator wires be twisted together or otherwise short-circuited on the surface before they are taken into the mine, and that this "short" be maintained until just before actual blasting is done. Carry all detonators to and from the mine in insualted boxes, and when about to use them still take care that the ends do not come in contact with live electric circuits or apparatus.

As black blasting powder is readily ignited from an electric flash, great care should be used to keep powder containers away from electric wires or apparatus, and especial care should be used in transporting black powder in mines containing electric wiring. All powder should be transported in special cars or boxes so constructed that the inside of the compartment is free from metal such as nails, scres, or bolts which might carry an electric current to the powder container. Notall blasting machines are safe for use in gassy mines. Machines satisfactory for single-shot unit which are on the Bureau of Mines permissible list have been tested for use in gassy atmospheres, and they do not give a spark that will ignite methane. Even the small hand-operated blasting machines commonly used for firing from one to three shots are capable of producing a spark that will ignite gas, hence it is unsafe to fire more than one shot at a time when using any type of electrical blasting machine where explosive gas may be present.

Permanent lines used in electric shot-firing should be kept away from other electric circuits and where they extend outside the mine they should be protected from lighting discharges. Ample switches should be provided for keeping the circuit open, except when the shots are being fired. Well-insulated rubber-covered wire should be used for temporary and portable shot-firing lines to minimize the danger of premature shots due to the contact of the line with other circuits.

The bureau's attention has been called to the overheating of detonator leg wires as a source of gas ignition. A preliminary investigation of the hazard resulted in the following recommendations: (1) Connect the detonators in parallel-series, series-parallel, or straight series; (2) limit the time length of connection to the firing supply to from 0.2 to 0.15 second; (3) use electric detonators with copper leg wires; (4) use a firing current supply having the lowest standard voltage that will satisfactorily fire all of the detonators as connected - for example, do not fire from a 600-volt circuit if 220 volts would be ample to give at least 2 amperes through every detonator; (5) use an ungrounded firing circuit.

In any shot-firing system the circuit should be so arranged that not less than 1.50 amperes will pass through the bridge wire of the detonator; although less current may fire a given detonator, different detonators vary in



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resistance and there should be sufficient surplus current to surely fire any and all of them.

## PREVENTION OF ELECTRIC-HAULAGE ACCIDENTS

Haulage accidents rank second in their toll of life and limb, being only exceeded by accidents from falls of roof.

In the old days of animal haulage the rear motive works of the mule accounted for many accidents. In modern mining the mule is being replaced by the electric locomotive, the electric hoist and various kinds of belt conveyors. The tremendous increase in speed effected by electric transportation methods as compared to animal haulage accounts in part for the high percentage of accidents charged to transportation. Haulage accidents underground are more numerous than those above ground partly because of the number of men involved and partly because of the natural difficulties encountered in underground workings, such as lack of light and space.

From the bureau's accident statistics it is found that 360 fatalities occurred underground in the year 1925 and 431 in the year 1926 from mine cars and locomotives, while 40 and 50 occurred on surface for the respective periods. Although these accidents were not segregated as to type of haulage, a large proportion of them were connected with electrically propelled cars or locomotives.

Some causes of haulage accidents are: wrecks due to trips jumping the tracks or to the breaking of rope or couplings, tripping and falling under cars and locomotives, getting squeezed between cars or between a car and the rib or roof, making flying switches or pushing cars instead of pulling them, and numerous other practices and conditions most of which are unnecessary.

### Suggestions for Improvement

The following suggestions are offered as partial remedies for reducing electric-haulage accidents: (a) Provide and maintain good brakes on all haulage equipment; (b) provide and maintain good road beds, ample weight of track rails, and suitable frogs and switches; (c) provide and maintain in proper condition a separate travelway for the men; keep the roadway clean from rib to rib; (d) where men must travel on haulageways, provide sufficient plainly marked manholes and maintain proper means of access to them; (e) provide well-lighted roadways; (f) provide and maintain ample clearance to one side of the roadway; (g) keep the timbering in good condition; (h) provide and maintain tail-lamp signals on all trips; (i) provide and maintain ample headlig[illegible]) provide runaway switches on all slopes and planes; (k) provide, mai[illegible]d use gongs on all locomotives; (l) prohibit excessive speed; (m) enfor[illegible]pline in regard to riding locomotives, loaded cars, cages, trips, etc[illegible](n) prohibit the making of flying switches and eliminate the pushing of t[illegible] cars.



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A firm roadbed with ample clearance at least on one side, and a well-kept, properly manned rolling stock will go a long way toward reducing haulage accidents. Instruction in accident prevention and proper discipline needs to be kept up if the best results are to be obtained. Conditions in a mine will never reach any high degree of safety until the safety idea has been sold to the man higher up.

## MINE-FIRE PREVENTION

Next to open lights, electricity is most dangerous as a source of mine fires. There are many ways in which electric circuits or apparatus may bring about a fire. Any machine which is overloaded or which has become worn out in service may break down, causing electric arcs and flashes capable of igniting any inflammable material close at hand. Every electric circuit is a possible source of fire hazard. Circuits can cause flashes when the wiring becomes grounded, when the circuit is opened under load (accidental separation of wires by fall), and by the short-circuiting of wires of opposite polarity.

Certain apparatus such as switches, fuses, and circuit-breakers flash and give off arcs under normal operation. Oil-filled apparatus is especially dangerous if the oil once becomes ignited because of the failure of the apparatus. Stationary electric-lamp bulbs may start a fire from the heat generated if they are installed too close to inflammable material.

### Good Installation the Best Safeguard

Many of the foregoing dangers are cured by proper installation of apparatus and circuits. All electric machinery should be installed in spacious, well-supported, fireproof rooms and on substantial fireproof foundations. Insulators should be placed close enough together to keep the wires from touching coal, rock, or timbers. Wires should never be run over timbers or placed where they can not be readily inspected. Temporary wiring should be discouraged; at any rate, temporary wire installations should be replaced within a few days by safely arranged permanent installations. Stations containing oil-filled equipment, such as transformers, should be so arranged that if for any cause oil is spilled it will not escape from the room. The room should have suitable fireproof doors which when closed will quickly seal the area.

### Protection from Overloads

All circuits and apparatus should be of sufficient size to perform their work without overheating and should be protected by circuit-interrupting devices against sustained overloads. Automatic reclosing circuit-breakers are proving successful on the main-line circuit, but would probably add to the fire hazard if used on branch circuits.



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## Cleanliness

Rooms containing electrical equipment should be kept free from inflammable material. All wiring should be kept clear of inflammable material. Fire fighting equipment should be kept in every underground station suitable for extinguishing electrical fires. Grease and oil should not be allowed to collect on or about electrical apparatus.

## The Safety Side of Electrical Equipment

Although electricity for some usages in mines has added to the fire hazards, this is not true of electricity as used for mine illumination and shot-firing. The electric cap lamp has replaced thousands of open lights, which are always a potential fire hazard. Electric shot-firing, which does away with the fuse and in many cases with the open light for igniting it, also reduces the fire hazard. One chief mine inspector in commenting on the Bureau of Mine's work states that the aid of the Bureau of Mines in developing the electric cap lamp alone is worth the whole cost of maintaining its electrical section since its inception.

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